A REVOLVING SINTERED-SLEEVE NOZZLE FOR GENERATING PESTICIDE SPRAY PARTICLES

ARS-S-7
April 1973

SOUTHERN REGION

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

in cooperation with

Coastal Plain Experiment Station
University of Georgia

CONTENTS

A REVOLVING SINTERED-SLEEVE NOZZLE FOR GENERATING PESTICIDE SPRAY PARTICLES

By E. A. Harrell, J. R. Young, and W. W. Hare [1]

Equipment to generate pesticide particles of a given size would help researchers evaluate sprays in insect control programs. Particle generators in use today primarily generate particles larger than 50 microns in diameter [2 3 4 5]. We are not aware of equipment capable of uniformily generating particles in sizes less than 50 microns. In this study we tested a revolving sintered-sleeve nozzle with 2-, 10-, 40-, and 60-micron pores. This nozzle system produced particles having a smaller particle-size range than conventional nozzle systems. However, the particle sizes followed a bimodal distribution.

MATERIALS AND METHODS

The revolving sintered-sleeve nozzle consists primarily of a 12-volt d.c. motor, a sintered stainless-steel cylindrical sleeve (2.75 inches in diameter by 3 inches long), and an adapter (fig. 1). The adapter connects the sleeve with the motor and forms a passageway for pesticides to enter the sleeve. The centrifugal force of the revolving sleeve distributes the pesticide on the inside and forces it out through the pores, thereby breaking it into small particles.

The nozzle was mounted with its rotational axis horizontal on a rigid frame inside a rectangular sheet-metal cover. The cover was designed to protect the operator in case of sleeve disintegration at high speeds. The speed was controlled by a variable-voltage d.c. power supply and monitored with a stroboscope (GE 1531-8B). Liquid flow was metered into the sleeve by a Master-Flex pump (model 7017) with a 3/8-inch-o.d. Tygon hose. The pump was driven by a Zeromax variable-speed motor.

Samples for particle-size determinations were taken by manually passing a petri dish under the nozzle. The spray particles were caught in a thixotropic solution[6] prepared to suspend oil particles. The particle diameters were measured in less than 5 minutes after collection with a dissecting microscope equipped with a calibrated image-splitting eyepiece. Particles were selected randomly by using a metal disk with four 0.187-inch-diameter holes spaced evenly on a 1.062-inch-diameter circle. The disk was placed under the petri dishes, which blacked out all light except that passing through the 0.187-inch holes. Only the particles over these holes were measured.

A randomized block design with six replications was used. Each replication consisted of measuring 20 particles from a petri dish. Particle sizes were measured with interchangeable sleeves of four pore sizes (2, 10, 40, and 60 microns), at six speeds (2,000, 4,000, 6,000, 8,000, 10,000, and about 12,000 revolutions per minute), and four liquid flow rates (15, 30, 45, and 60 milliliters per minute). The spray was undiluted malathion (95 percent).

Two pneumatic nozzles were used in a comparison test: the Tifton ultra-low-volume and the spraying systems F-1. The flow rate sprayed with these nozzles was that which would normally

1. Agricultural engineer, entomologist, and agricultural engineer, respectively, Southern Region, Agricultural Research Service, U. S. Department of Agriculture, Tifton, Ga.

2. Mason, B. J., Jayarantne, O. W., and Woods, J. D. An improved vibrating capillary device for producing uniform water droplets of 15- to 500-micron radius. Jour. Sci. Instruments 40: 247-249. 1963.

3. Burt, E. C., Smith, D. B., and Lloyd, E. P. A rotary disc device for applying ultra-low-volume (undiluted) pesticides with ground equipment. Jour. Econ. Entomol. 59: 1487-1489. 1966.

4. Smith, D. B., Burt, E. C., and Benci, F. J. Design of a spinning disc, droplet separator and the determination of the size and density of droplets deposited on cotton foliage. Amer. Soc. Agr. Engin. Trans. 1970: 664-668. 1970.

5. Williamson, R. E., and Threadgill, E. D. A droplet generator for wind tunnel studies of spray drift. Amer. Soc. Agr. Engin. Paper 70-536. (American Society of Agricultural Engineers, St. Joseph, Mich. 49085) 1970.

6. Daum, R. J., Burt, E. C., and Smith, D. B. Capturing spray droplets with thixotropic solutions. Jour. Econ. Entomol. 61: 1120-1121. 1968.

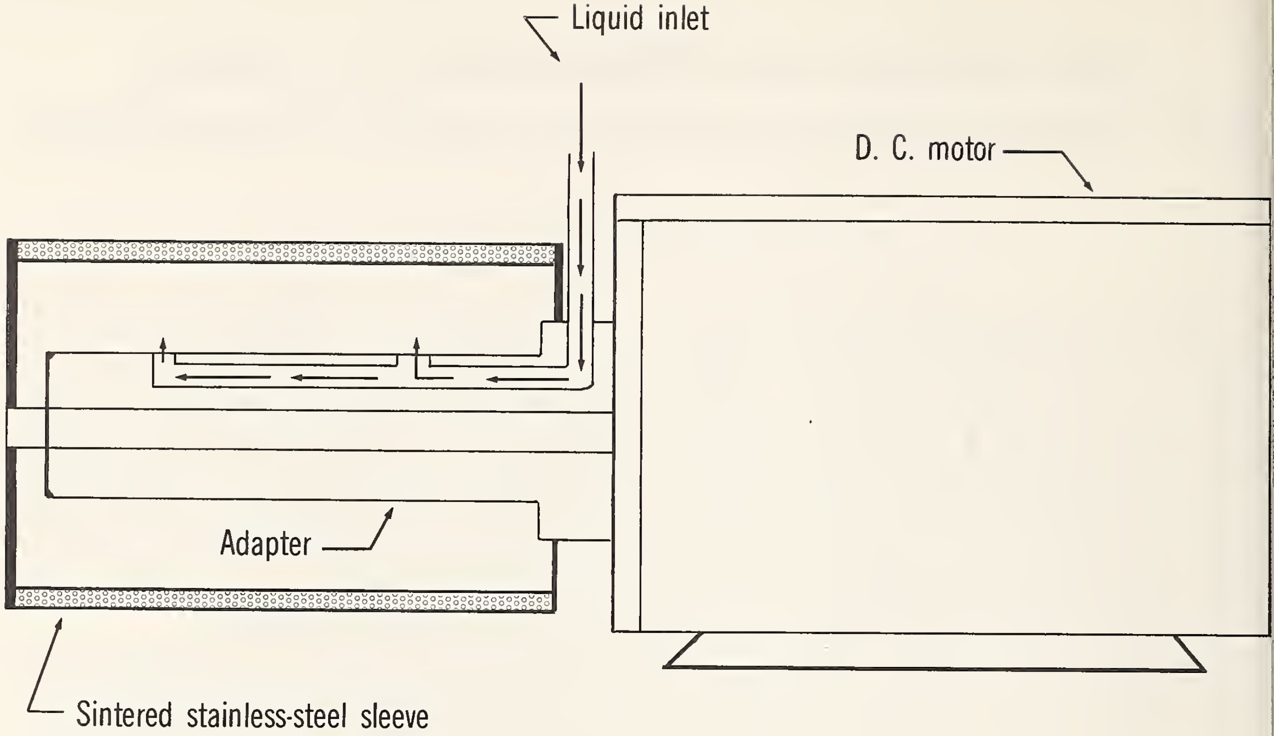

Figure 1. — Schematic of a revolving sintered-sleeve nozzle for generating pesticide spray particles.

be used to apply 0.5 to 2.0 pints per acre with our ground equipment.[7] The atomizing air pressure was either 10 or 20 pounds per square inch with a tank liquid pressure of 10 pounds per square inch.

RESULTS AND DISCUSSION

A plot of the number of particles versus particle size resulted in a bimodal distribution (figs. 2 and 3) that was not consistent with changes in speed, sleeve pore size, or flow rate. The mean particle size for the complete experiment was 45.57 microns (table 1). The mean particle size from the 2-, 10-, 40-, and 60-micron-pore sleeves for all speeds and volumes was 43.92, 47.02, 44.30, and 47.06 microns, respectively. The mean deviated less than ±2 microns from the overall mean. The largest particles were produced by the 60-micron-pore sleeve and the smallest by the 2-micron-pore sleeve.

The mean particle size generally decreased as the nozzle speed was increased at each of the four flow rates. However, when the nozzles were operated at speeds greater than 6,000 revolutions per minute, the particle sizes were about the same at each volume. The average particle sizes at 60 milliliters per minute were 63.96, 40.16, 44.50, and 43.46 microns from the 2-, 10-, 40-, and 60-micron-pore sleeves, respectively. This may be compared with particle sizes of 33.95, 48.47, 47.78, and 48.67 microns from the 2-, 10-, 40-, and 60-micron-pore sleeves at a flow rate of 15 milliliters per minute. The major difference was with the 2-micron-pore sleeve. The average particle size was 33.95 microns at 15 milliliters of spray per minute and 63.96 at 60 milliliters per minute. Particle sizes from the other sleeves were almost unchanged from the smallest to the largest flow rate.

The Tifton ultra-low-volume nozzle produced an average particle size of 39.97 microns at 10 pounds per square inch and 36.15 microns at 20 pounds per square inch atomizing pressure (table 2). The spraying systems F-1 nozzle produced an average of 20.49- and 20.3-micron particle sizes at 10 and 20 pounds per square inch, respectively. The mean particle size from both nozzles did not change significantly with changes in either air pressure or liquid flow rate. The mean particle size

7. Harrell, E. A., Hare, W. W., and Sparks, A. N. Experimental ground equipment to apply concentrated dusts and liquid pesticides for insect control on sweet corn. Jour. Econ. Entomol. 63: 382-385. 1970.

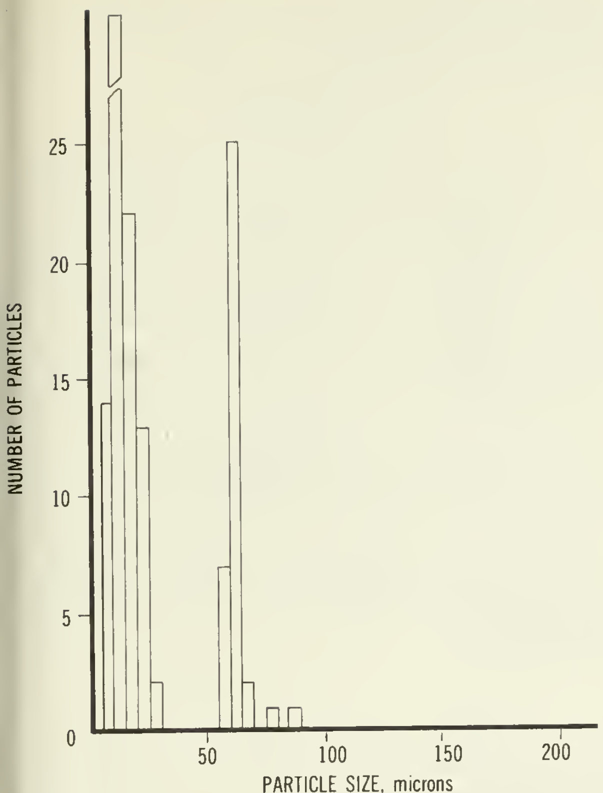

Figure 2.—Spray particle distribution generated by 2-micron sleeve pores at 6,000 r.p.m. and 30 ml./min. of malathion.

from both pneumatic nozzles was smaller than that from the revolving nozzle.

Because the particle sizes generated with the revolving sintered-sleeve nozzle resulted in a bimodal distribution, standard analysis of variance could not be used. Thus, the particle sizes were divided into eight size categories for analysis. The particle-size categories from the revolving sintered nozzles were grouped by sleeve pore size (table 3), by speed (table 4), and by flow rates (table 5); and the pneumatic nozzles were grouped by nozzle (table 6), pressure (table 7), and by flow rates (table 8). About half of the particles generated by the 2-micron pores were between 30 and 50 microns, and almost no particles were larger than 50 microns at sqeeds above 8,000 revolutions per minute with 15 milliliters per minute. Except for particle sizes less than 10 microns, the 10-micron-pore sleeve produced particles very similar in size to those produced by the 2-micron-pore sleeve when the nozzle was operated at the same speed and flow rate. The 2-micron-pore sleeve produced more particles less than 10 microns than did the 10-, 40-, or 60-micron-pore sleeves. As the sleeve pore size increased, particle size increased only slightly. Most particles were between 15 and 50 microns. At the lower speeds, the particle size was largest. All sleeves operating at 2,000 revolutions per minute produced about 65 percent of the particles larger than 50 microns and about 50 percent of those larger than 100 microns. Almost no particles were generated with a diameter greater than 100 microns at speeds above 6,000 revolutions per minute. As the speeds were increased to 8,000 revolutions per minute, the maximum particle size decreased to about 75 microns, and above 10,000 revolutions per minute the maximum size was about 50 microns. The flow rate of malathion had little effect on particle size.

Analysis of variance of the number of particles within each category of particle sizes showed that the sleeves differed significantly in their ability to generate particles smaller than 100 microns (table 9). The particle sizes from 10 to 14.9 and from 20 to 29.9 microns were significantly different at the 5-percent level,

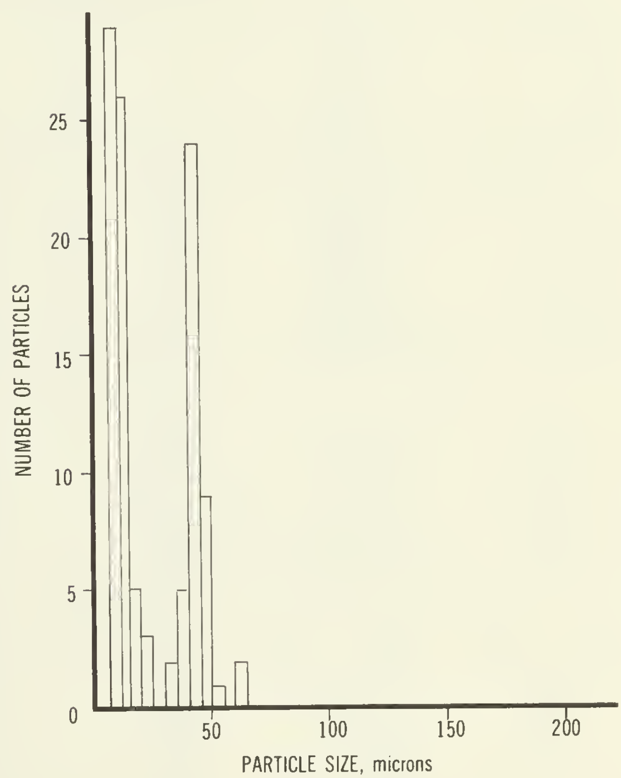

Figure 3.—Spray particle distribution generated by 2-micron sleeve pores at 8,000 r.p.m. and 60 ml./min. of malathion.

whereas all other size differences were highly significant among the sleeves. The speeds were significantly different at the 1-percent level within all size categories. Liquid flow rates had little or no effect on particles within each size category. The numbers of particles generated were significantly different at less than 10 and greater than 75 microns. There were no differences among replications.

To further separate means in this series of tests, a Duncan's multiple-range test was run (table 10). The means in this table are an average of the number of particles in each category throughout the test (20 particles per six replications). The sleeves were not significantly different in their ability to generate particles above 100 microns in diameter. Number of particles in the other size categories varied. Changes in speed produced significant differences in particle size of the categories, while changes in volume produced fewer differences. Differences among replications were not significant. To generate smaller particles, the speed should be above 6,000 revolutions per minute.

CONCLUSIONS

The data resulting from this study indicate that sleeve pore size is relatively unimportant in generating particles of a specific size. All sleeves produced particles having bimodal distribution. The speed of sleeve rotation generally influenced particle sizes more than either sleeve pore size or liquid flow rate. However, this influence was more pronounced at speeds less than 6,000 revolutions per minute. As the speed was increased, the particle sizes tended to become smaller. Changes in the liquid flow rate of spray had little or no effect on particle size. Even though the revolving sintered-sleeve nozzle did not produce particles of a specific size, it produced a narrower range of particle sizes than that reported for conventional nozzle systems.

TABLE 1.—Average[1] particle sizes of malathion generated by a revolving sintered-sleeve nozzle at various flow rates, speeds, and pore sizes

Flow rate	Nozzle speed	Pore size of sleeve, microns				Avg. particle size.
		2	10	40	60	
Ml./min.	*R.p.m.*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*
15	2,000	46.17	129.95	124.87	112.97	103.49
15	4,000	44.10	54.22	46.63	70.47	53.85
15	6,000	32.90	37.33	36.18	32.37	34.69
15	8,000	29.42	27.40	31.38	29.03	29.31
15	10,000	25.40	22.18	24.02	25.43	24.26
15	11,800	25.68	19.72	23.58	21.75	22.68
Avg. particle size		33.95	48.47	47.78	48.67	44.71
30	2,000	104.47	119.62	132.07	117.02	118.29
30	4,000	67.38	72.53	51.05	61.13	63.02
30	6,000	29.32	35.98	35.53	37.27	34.52
30	8,000	24.77	40.23	27.87	32.02	31.22
30	10,000	22.51	29.54	25.20	22.97	25.05
30	11,800	22.77	30.48	21.60	20.07	23.73
Avg. particle size		45.20	54.73	48.89	48.41	49.30
45	2,000	47.57	99.62	66.65	124.62	84.61
45	4,000	41.70	44.22	43.12	56.38	46.35
45	6,000	30.80	36.62	30.13	34.33	32.97
45	8,000	35.42	35.20	28.32	27.18	31.58
45	10,000	20.75	23.28	23.50	22.48	22.50
45	11,800	19.12	29.37	24.52	21.30	23.58
Avg. particle size		32.56	44.72	36.04	47.71	40.26

TABLE 1.—Average[1] particle sizes of malathion generated by a revolving sintered-sleeve nozzle at various flow rates, speeds, and pore sizes—Continued

Flow rate	Nozzle speed	Pore size of sleeve, microns				Avg. particle size.
		2	10	40	60	
Ml./min.	*R.p.m.*	*Microns*	*Microns*	*Microns*	*Microns*	*Microns*
60	2,000	169.50	66.68	101.30	121.93	114.85
60	4,000	114.73	57.43	47.80	36.30	64.06
60	6,000	35.78	35.85	33.02	29.92	33.64
60	8,000	22.05	30.87	34.30	26.27	28.37
60	10,000	23.00	26.60	26.70	22.57	24.72
60	11,000	18.70	23.53	23.90	23.78	22.48
	Avg. particle size	63.96	40.16	44.50	43.46	48.02
	Avg. particle size, total experiment	43 92	47.02	44.30	47.06	45.57

[1] Average of 120 observations.

TABLE 2.—Average[1] particle sizes of malathion generated by pneumatic nozzles at various flow rates and atomizing pressures

Flow rate	Atomizing air pressure	Nozzles		Avg. particle size
		Tifton ultra-low-volume	Spraying systems F-1	
Ml./min.	*P.s.i.*	*Microns*	*Microns*	*Microns*
12.1	10	41.22	17.17	29.19
18.15	10	50.22	16.90	33.56
24.20	10	38.77	25.67	32.22
36.30	10	29.67	22.22	25.95
Avg. particle size		39.97	20.49	30.23
12.1	20	43.08	20.13	31.60
18.15	20	26.85	20.25	23.55
24.20	20	34.93	23.15	31.54
36.30	20	34.75	17.70	26.22
Avg. particle size		36.15	20.31	28.23

[1] Average of 120 observations.

TABLE 3.—Number of malathion particles in various size categories produced at various nozzle speeds and flow rates, grouped by sleeve pore size

Sleeve pore size	Nozzle speed	Flow rate	Particle size, microns							
			<10	10–14.9	15–19.9	20–29.9	30–49.9	50–74.9	75–99.9	>100
Microns	*R.p.m.*	*Ml./min.*	*Number of particles*							
2	2,000	15	11	22	17	16	1	0	51	2
2	4,000	15	0	8	26	36	7	0	43	0
2	6,000	15	26	20	20	2	1	48	2	1
2	8,000	15	30	15	5	0	66	4	0	0
2	10,000	15	27	12	2	13	66	0	0	0
2	11,800	15	12	4	0	74	30	0	0	0

TABLE 3.—Number of malathion particles in various size categories produced at various nozzle speeds and flow rates, grouped by sleeve pore size—Continued

Sleeve pore size	Nozzle speed	Flow rate	Particle size, microns							
			<10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	>100
Microns	*R.p.m.*	*Ml./min.*	*Number of particles*							
2	2,000	30	1	0	1	5	29	27	7	50
2	4,000	30	2	9	8	18	4	1	76	3
2	6,000	30	10	29	28	17	1	33	2	0
2	8,000	30	28	32	7	1	51	1	0	0
2	10,000	30	34	25	5	3	51	2	0	0
2	11,200	30	30	16	3	18	53	0	0	0
2	2,000	45	11	15	9	25	14	0	44	2
2	4,000	45	9	11	18	37	8	0	36	1
2	6,000	45	24	27	20	3	0	42	4	0
2	8,000	45	15	18	13	0	51	22	1	0
2	10,000	45	44	13	6	4	52	1	0	0
2	11,000	45	48	21	6	0	45	0	0	0
2	2,000	60	0	0	0	0	0	4	6	110
2	4,000	60	0	1	1	6	4	3	24	81
2	6,000	60	12	28	18	27	7	0	26	2
2	8,000	60	42	24	7	4	38	5	0	0
2	10,000	60	25	30	14	6	41	4	0	0
2	10,500	60	36	32	12	6	33	1	0	0
10	2,000	15	2	0	0	0	7	35	17	59
10	4,000	15	1	12	20	29	3	0	52	3
10	6,000	15	3	21	23	12	0	61	0	0
10	8,000	15	24	21	16	4	43	12	0	0
10	10,000	15	35	21	8	3	49	4	0	0
10	11,000	15	37	14	11	26	32	0	0	0
10	2,000	30	9	3	2	5	13	17	12	59
10	4,000	30	0	2	4	19	9	0	81	5
10	6,000	30	12	18	19	20	1	47	3	0
10	8,000	30	0	7	6	2	96	9	0	0
10	10,000	30	22	25	14	3	51	5	0	0
10	11,600	30	2	6	7	11	94	0	0	0
10	2,000	45	3	3	0	1	12	46	16	39
10	4,000	45	1	9	19	45	9	2	28	7
10	6,000	45	12	22	16	15	0	53	2	0
10	8,000	45	8	14	16	2	64	16	0	0
10	10,000	45	28	20	16	4	49	3	0	0
10	11,000	45	0	20	12	4	81	3	0	0
10	2,000	60	0	0	3	7	41	46	7	16
10	4,000	60	5	10	11	16	22	1	44	11
10	6,000	60	0	26	24	19	2	48	1	0
10	8,000	60	20	18	14	11	28	29	0	0
10	10,000	60	16	24	15	1	60	4	0	0
10	11,000	60	24	20	19	3	52	2	0	0
40	2,000	15	1	1	2	2	11	26	14	63
40	4,000	15	1	20	17	18	2	44	16	2
40	6,000	15	12	14	18	25	3	46	2	0
40	8,000	15	13	26	22	5	14	40	0	0
40	10,000	15	29	16	11	3	59	2	0	0
40	11,200	15	28	15	5	12	60	0	0	0

TABLE 3.—Number of malathion particles in various size categories produced at various nozzle speeds and flow rates, grouped by sleeve pore size—Continued

Sleeve pore size	Nozzle speed	Flow rate	Particle size, microns							
			<10	10 – 14.9	15 – 19.9	20 – 29.9	30 – 49.9	50 – 74.9	75 – 99.9	>100
Microns	*R.p.m.*	*Ml./min.*	*Number of particles*							
40	2,000	30	0	1	3	2	16	20	10	68
40	4,000	30	3	10	17	20	14	2	52	2
40	6,000	30	6	20	26	19	2	42	5	0
40	8,000	30	23	27	16	9	17	27	1	0
40	10,000	30	20	22	16	6	50	6	0	0
40	11,600	30	25	23	13	14	45	0	0	0
40	2,000	45	0	1	6	7	37	45	11	13
40	4,000	45	1	12	19	34	20	0	28	6
40	6,000	45	8	27	29	18	6	29	3	0
40	8,000	45	19	23	20	8	24	26	0	0
40	10,000	45	27	24	10	4	54	1	0	0
40	11,400	45	18	15	18	11	57	1	0	0
40	2,000	60	0	1	1	1	13	49	12	43
40	4,000	60	1	11	11	31	22	7	31	6
40	6,000	60	3	20	28	23	9	35	2	0
40	8,000	60	5	11	15	7	69	13	0	0
40	10,000	60	14	25	16	3	56	5	1	0
40	10,800	60	15	28	18	5	50	4	0	0
60	2,000	15	0	2	3	4	28	22	4	57
60	4,000	15	1	1	5	8	30	6	52	17
60	6,000	15	7	18	26	24	6	37	2	0
60	8,000	15	7	24	19	16	45	9	0	0
60	10,000	15	17	20	11	5	67	0	0	0
60	10,800	15	20	26	16	10	46	2	0	0
60	2,000	30	1	1	5	2	14	29	16	52
60	4,000	30	0	9	7	19	32	6	26	21
60	6,000	30	4	17	14	20	22	40	3	0
60	8,000	30	5	23	15	19	35	23	0	0
60	10,000	30	19	33	11	8	47	2	0	0
60	10,500	30	27	19	25	10	39	0	0	0
60	2,000	45	1	0	2	2	10	24	17	64
60	4,000	45	4	6	11	23	21	2	42	11
60	6,000	45	7	16	17	25	18	36	1	0
60	8,000	45	17	34	12	11	27	19	0	0
60	10,000	45	21	20	24	13	40	2	0	0
60	11,100	45	32	23	7	11	47	0	0	0
60	2,000	60	0	0	1	2	10	29	23	55
60	4,000	60	4	14	15	35	28	3	18	3
60	6,000	60	14	17	18	26	21	20	4	0
60	8,000	60	11	26	21	22	27	13	0	0
60	10,000	60	20	22	21	16	39	2	0	0
60	11,400	60	19	16	16	12	57	0	0	0

TABLE 4.—Number of malathion particles in various size categories produced by various sleeve pore sizes and flow rates, grouped by nozzle speed

Nozzle speed	Sleeve pore size	Flow rate	Particle size, microns							
			< 10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	> 100
R.p.m.	*Microns*	*Ml./min.*	*Number of particles*							
2,000	2	15	11	22	17	16	1	0	51	2
2,000	2	30	1	0	1	5	29	27	7	50
2,000	2	45	11	15	9	25	14	0	44	2
2,000	2	60	0	0	0	0	0	4	6	110
2,000	10	15	2	0	0	0	7	35	17	59
2,000	10	30	9	3	2	5	13	17	12	59
2,000	10	45	3	3	0	1	12	46	16	39
2,000	10	60	0	0	0	7	41	46	7	16
2,000	40	15	1	1	2	2	11	26	14	63
2,000	40	30	0	1	3	2	16	20	10	68
2,000	40	45	0	1	6	7	37	45	11	13
2,000	40	60	0	1	1	1	13	49	12	43
2,000	60	15	0	2	3	4	28	22	4	57
2,000	60	30	1	1	5	2	14	29	16	52
2,000	60	45	1	0	2	2	10	24	17	64
2,000	60	60	0	0	1	2	10	29	23	55
4,000	2	15	0	8	26	36	7	0	43	0
4,000	2	30	2	9	8	18	4	1	76	3
4,000	2	45	9	11	18	37	8	0	36	1
4,000	2	60	0	1	1	6	4	3	24	81
4,000	10	15	1	12	20	29	3	0	52	3
4,000	10	30	0	2	4	19	9	0	81	5
4,000	10	45	1	9	19	45	9	2	28	7
4,000	10	60	5	10	11	16	22	1	44	11
4,000	40	15	1	20	17	18	2	44	16	2
4,000	40	30	3	10	17	20	14	2	52	2
4,000	40	45	1	12	19	34	20	0	28	6
4,000	40	60	1	11	11	31	22	7	31	6
4,000	60	15	1	1	5	8	30	6	52	17
4,000	60	30	0	9	7	19	32	6	26	21
4,000	60	45	4	6	11	23	21	2	42	11
4,000	60	60	4	14	15	35	28	3	18	3
6,000	2	15	26	20	20	2	1	48	2	1
6,000	2	30	10	29	28	17	1	33	2	0
6,000	2	45	24	27	20	3	0	42	4	0
6,000	2	60	12	28	18	27	7	0	26	2
6,000	10	15	3	21	23	12	0	61	0	0
6,000	10	30	12	18	19	20	1	47	3	0
6,000	10	45	12	22	16	15	0	53	2	0
6,000	10	60	0	26	24	19	2	48	1	0
6,000	40	15	12	14	18	25	3	46	2	0
6,000	40	30	6	20	26	19	2	42	5	0
6,000	40	45	8	27	29	18	6	29	3	0
6,000	40	60	3	20	28	23	9	35	2	0

TABLE 4.—Number of malathion particles in various size categories produced by various sleeve pore sizes and flow rates, grouped by nozzle speed —Continued

Nozzle speed	Sleeve pore size	Flow rate	Particle size, microns							
			< 10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	> 100
R.p.m.	*Microns*	*Ml./min.*	*Number of particles*							
6,000	60	15	7	18	26	24	6	37	2	0
6,000	60	30	4	17	14	20	22	40	3	0
6,000	60	45	7	16	17	25	18	36	1	0
6,000	60	60	14	17	18	26	21	20	4	0
8,000	2	15	30	15	5	0	66	4	0	0
8,000	2	30	28	32	7	1	51	1	0	0
8,000	2	45	15	18	13	0	51	22	1	0
8,000	2	60	42	24	7	4	38	5	0	0
8,000	10	15	24	21	16	4	43	12	0	0
8,000	10	30	0	7	6	2	96	9	0	0
8,000	10	45	8	14	16	2	64	16	0	0
8,000	10	60	20	18	14	11	28	29	0	0
8,000	40	15	13	26	22	5	14	40	0	0
8,000	40	30	23	27	16	9	17	27	1	0
8,000	40	45	19	23	20	8	24	26	0	0
8,000	40	60	5	11	15	7	69	13	0	0
8,000	60	15	7	24	19	16	45	9	0	0
8,000	60	30	5	23	15	19	35	23	0	0
8,000	60	45	17	34	12	11	27	19	0	0
8,000	60	60	11	26	21	22	27	13	0	0
10,000	2	15	27	12	2	13	66	0	0	0
10,000	2	30	34	25	5	3	51	2	0	0
10,000	2	45	44	13	6	4	52	1	0	0
10,000	2	60	25	30	14	6	41	4	0	0
10,000	10	15	35	21	8	3	49	4	0	0
10,000	10	30	22	25	14	3	51	5	0	0
10,000	10	45	28	20	16	4	49	3	0	0
10,000	10	60	16	24	15	1	60	4	0	0
10,000	40	15	29	16	11	3	59	2	0	0
10,000	40	30	20	22	16	6	50	6	0	0
10,000	40	45	27	24	10	4	54	1	0	0
10,000	40	60	14	25	16	3	56	5	1	0
10,000	60	15	17	20	11	5	67	0	0	0
10,000	60	30	19	33	11	8	47	2	0	0
10,000	60	45	21	20	24	13	40	2	0	0
10,000	60	60	20	22	21	16	39	2	0	0
11,800	2	15	12	4	0	74	30	0	0	0
11,200	2	30	30	16	3	18	53	0	0	0
11,000	2	45	48	21	6	0	45	0	0	0
10,500	2	60	36	32	12	6	33	1	0	0
11,000	10	15	37	14	11	26	32	0	0	0
11,600	10	30	2	6	7	11	94	0	0	0
11,000	10	45	0	20	12	4	81	3	0	0
11,000	10	60	24	20	19	3	52	2	0	0

TABLE 4.—Number of malathion particles in various size categories produced by various sleeve pore sizes and flow rates, grouped by nozzle speed —Continued

Nozzle speed	Sleeve pore size	Flow rate	Particle size, microns							
			< 10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	> 100
R.p.m.	*Microns*	*Ml./min.*	*Number of particles*							
11,200	40	15	28	15	5	12	60	0	0	0
11,600	40	30	25	23	13	14	45	0	0	0
11,400	40	45	18	15	18	11	57	1	0	0
10,800	40	60	15	28	18	5	50	4	0	0
10,800	60	15	20	26	16	10	46	2	0	0
10,500	60	30	27	19	25	10	39	0	0	0
11,100	60	45	32	23	7	11	47	0	0	0
11,400	60	60	19	16	16	12	57	0	0	0

TABLE 5.—Number of malathion particles in various size categories produced with various sleeves operating at different speeds, grouped by flow rates

Flow rate	Sleeve pore size	Nozzle speed	Particle size, microns							
			<10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	> 100
Ml./min.	*Microns*	*R.p.m.*	*Number of particles*							
15	2	2,000	11	22	17	16	1	0	51	2
15	2	4,000	0	8	26	36	7	0	43	0
15	2	6,000	26	20	20	2	1	48	2	1
15	2	8,000	30	15	5	0	66	4	0	0
15	2	10,000	27	12	2	13	66	0	0	0
15	2	11,800	12	4	0	74	30	0	0	0
15	10	2,000	2	0	0	0	7	35	17	59
15	10	4,000	1	12	20	29	3	0	52	3
15	10	6,000	3	21	23	12	0	61	0	0
15	10	8,000	24	21	16	4	43	12	0	0
15	10	10,000	35	21	8	3	49	4	0	0
15	10	11,000	37	14	11	26	32	0	0	0
15	40	2,000	1	1	2	2	11	26	14	63
15	40	4,000	1	20	17	18	2	44	16	2
15	40	6,000	12	14	18	25	3	46	2	0
15	40	8,000	13	26	22	5	14	40	0	0
15	40	10,000	29	16	11	3	59	2	0	0
15	40	11,200	28	15	5	12	60	0	0	0
15	60	2,000	0	2	3	4	28	22	4	57
15	60	4,000	1	1	5	8	30	6	52	17
15	60	6,000	7	18	26	24	6	37	2	0
15	60	8,000	7	24	19	16	45	9	0	0
15	60	10,000	17	20	11	5	67	0	0	0
15	60	10,800	20	26	16	10	46	2	0	0
30	2	2,000	1	0	1	5	29	27	7	50
30	2	4,000	2	9	8	18	4	1	76	3
30	2	6,000	10	29	28	17	1	33	2	0
30	2	8,000	28	32	7	1	51	1	0	0
30	2	10,000	34	25	5	3	51	2	0	0
30	2	11,200	30	16	3	18	53	0	0	0

TABLE 5.—Number of malathion particles in various size categories produced with various sleeves operating at different speeds, grouped by flow rates—Continued

Flow rate	Sleeve pore size	Nozzle speed	Particle size, microns							
			<10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	> 100
Ml./min.	*Microns*	*R.p.m.*	*Number of particles*							
30	10	2,000	9	3	2	5	13	17	12	59
30	10	4,000	0	2	4	19	9	0	81	5
30	10	6,000	12	18	19	20	1	47	3	0
30	10	8,000	0	7	6	2	96	9	0	0
30	10	10,000	22	25	14	3	51	5	0	0
30	10	11,600	2	6	7	11	94	0	0	0
30	40	2,000	0	1	3	2	16	20	10	68
30	40	4,000	3	10	17	20	14	2	52	2
30	40	6,000	6	20	26	19	2	42	5	0
30	40	8,000	23	27	16	9	17	27	1	0
30	40	10,000	20	22	16	6	50	6	0	0
30	40	11,600	25	23	13	14	45	0	0	0
30	60	2,000	1	1	5	2	14	29	16	52
30	60	4,000	0	9	7	19	32	6	26	21
30	60	6,000	4	17	14	20	22	40	3	0
30	60	8,000	5	23	15	19	35	23	0	0
30	60	10,000	19	33	11	8	47	2	0	0
30	60	10,500	27	19	25	10	39	0	0	0
45	2	2,000	11	15	9	25	14	0	44	2
45	2	4,000	9	11	18	37	8	0	36	1
45	2	6,000	24	27	20	3	0	42	4	0
45	2	8,000	15	18	13	0	51	22	1	0
45	2	10,000	44	13	6	4	52	1	0	0
45	2	11,000	48	21	6	0	45	0	0	0
45	10	2,000	3	3	0	1	12	46	16	39
45	10	4,000	1	9	19	45	9	2	28	7
45	10	6,000	12	22	16	15	0	53	2	0
45	10	8,000	8	14	16	2	64	16	0	0
45	10	10,000	28	20	16	4	49	3	0	0
45	10	11,000	0	20	12	4	81	3	0	0
45	40	2,000	0	1	6	7	37	45	11	13
45	40	4,000	1	12	19	34	20	0	28	6
45	40	6,000	8	27	29	18	6	29	3	0
45	40	8,000	19	23	20	8	24	26	0	0
45	40	10,000	27	24	10	4	54	1	0	0
45	40	11,400	18	15	18	11	57	1	0	0
45	60	2,000	1	0	2	2	10	24	17	64
45	60	4,000	4	6	11	23	21	2	42	11
45	60	6,000	7	16	17	25	18	36	1	0
45	60	8,000	17	34	12	11	27	19	0	0
45	60	10,000	21	20	24	13	40	2	0	0
45	60	11,100	32	23	7	11	47	0	0	0
60	2	2,000	0	0	0	0	0	4	6	110
60	2	4,000	0	1	1	6	4	3	24	81
60	2	6,000	12	28	18	27	7	0	26	2
60	2	8,000	42	24	7	4	38	5	0	0
60	2	10,000	25	30	14	6	41	4	0	0
60	2	10,500	36	32	12	6	33	1	0	0

TABLE 5.—Number of malathion particles in various size categories produced with various sleeves operating at different speeds, grouped by flow rates—Continued

Flow rate	Sleeve pore size	Nozzle speed	Particle size, microns							
			<10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	>100
Ml./min.	*Microns*	*R.p.m.*	*Number of particles*							
60	10	2,000	0	0	3	7	41	46	7	16
60	10	4,000	5	10	11	16	22	1	44	11
60	10	6,000	0	26	24	19	2	48	1	0
60	10	8,000	20	18	14	11	28	29	0	0
60	10	10,000	16	24	15	1	60	4	0	0
60	10	11,000	24	20	19	3	52	2	0	0
60	40	2,000	0	1	1	1	13	49	12	43
60	40	4,000	1	11	11	31	22	7	31	6
60	40	6,000	3	20	28	23	9	35	2	0
60	40	8,000	5	11	15	7	69	13	0	0
60	40	10,000	14	25	16	3	56	5	1	0
60	40	10,800	15	28	18	5	50	4	0	0
60	60	2,000	0	0	1	2	10	29	23	55
60	60	4,000	4	14	15	35	28	3	18	3
60	60	6,000	14	17	18	26	21	20	4	0
60	60	8,000	11	26	21	22	27	13	0	0
60	60	10,000	20	22	21	16	39	2	0	0
60	60	11,400	19	16	16	12	57	0	0	0

TABLE 6.—Number of malathion particles in various size categories produced by two pneumatic nozzles operated at various speeds and flow rates

Nozzle	Atomizing air pressure	Flow rate of malathion	Particle size, microns							
			<10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	>100
	P.s.i.	*Ml./min.*	*Number of particles*							
TULV[1]	10	12.10	4	11	21	32	24	12	9	7
	10	18.15	11	14	16	17	29	19	8	6
	10	24.20	10	16	17	30	17	11	8	11
	10	36.30	5	15	14	19	32	23	7	5
	20	12.10	19	13	9	12	24	20	8	15
	20	18.15	14	20	11	28	28	14	4	1
	20	24.20	21	26	19	20	16	13	2	3
	20	36.30	22	24	9	18	23	9	6	9
SS F-1[2]	10	12.10	27	24	28	25	10	6	0	0
	10	18.15	17	18	14	28	35	6	2	0
	10	24.20	36	24	15	16	23	5	1	0
	10	36.30	38	20	11	17	24	5	4	1
	20	12.10	41	23	19	20	14	3	0	0
	20	18.15	17	25	14	33	28	3	0	0
	20	24.20	30	25	15	25	22	2	0	1
	20	36.30	33	23	17	30	17	0	0	0

[1] Tifton ultra-low-volume. [2] Spraying systems F-1.

TABLE 7.—Number of malathion particles in various size categories produced by two pneumatic nozzles, grouped by operating pressure

Atomizing air pressure	Nozzle	Flow rate	Particle size, microns							
			<10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	>100
P.s.i.		*Ml./min.*	*Number of particles*							
10	TULV[1]	12.10	4	11	21	32	24	12	9	7
10	TULV	18.15	11	14	16	17	29 .	19	8	6
10	TULV	24.20	10	16	17	30	17	11	8	11
10	TULV	36.30	5	15	14	19	32	23	7	5
10	SS F-1[2]	12.10	27	24	28	25	10	6	0	0
10	SS F-1	18.15	17	18	14	28	35	6	2	0
10	SS F-1	24.20	36	24	15	16	23	5	1	0
10	SS F-1	36.30	38	20	11	17	24	5	4	1
20	TULV	12.10	19	13	9	12	24	20	8	15
20	TULV	18.15	14	20	11	28	28	14	4	1
20	TULV	24.20	21	26	19	20	16	13	2	3
20	TULV	36.30	22	24	9	18	23	9	6	9
20	SS F-1	12.10	41	23	19	20	14	3	0	0
20	SS F-1	18.15	17	25	14	33	28	3	0	0
20	SS F-1	24.20	30	25	15	25	22	2	0	1
20	SS F-1	36.30	33	23	17	30	17	0	0	0

[1] Tifton ultra-low-volume. [2] Spraying systems F-1.

TABLE 8.—Number of malathion particles in various size categories produced by two pneumatic nozzles, grouped by flow rates

Flow rate	Nozzle	Atomizing air pressure	Particle size, microns							
			<10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	>100
Ml./min.		*P.s.i.*	*Number of particles*							
12.10	TULV[1]	10	4	11	21	32	24	12	9	7
12.10	TULV	20	19	13	9	12	24	20	8	15
18.15	TULV	10	11	14	16	17	29	19	8	6
18.15	TULV	20	14	20	11	28	28	14	4	1
24.20	TULV	10	10	16	17	30	17	11	8	11
24.20	TULV	20	21	26	19	20	16	13	2	3
36.30	TULV	10	5	15	14	19	32	23	7	5
36.30	TULV	20	22	24	9	18	23	9	6	9
12.10	SS F-1[2]	10	27	24	28	25	10	6	0	0
12.10	SS F-1	20	41	23	19	20	14	3	0	0
18.15	SS F-1	10	17	18	14	28	35	6	2	0
18.15	SS F-1	20	17	25	14	33	28	3	0	0
24.20	SS F-1	10	36	24	15	16	23	5	1	0
24.20	SS F-1	20	30	25	15	25	22	2	0	1
36.30	SS F-1	10	38	20	11	17	24	5	4	1
36.30	SS F-1	20	33	23	17	30	17	0	0	0

[1] Tifton ultra-low-volume. [2] Spraying systems F-1.

TABLE 9.—Analysis of variance "F" on number of particles within each size category generated by revolving sintered-sleeve nozzle

Source	D.F.	Particle size, microns							
		<10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	>100
Total Sum of squares	575	.....	.....	.....	.....	.....	.....	.....	.....
Model Sum of squares	110	6.47	4.7	3.6	5.2	11.2	12.6	10.7	10.8
Error Sum of squares	465	.....	.....	.....	.....	.....	.....	.....	.....
Sleeve	3	27.9**	3.0*	6.6**	2.8*	5.6**	34.0**	6.7**	2.0
Speed	5	94.8**	68.9**	37.6**	51.8**	185.0**	192.4**	187.3**	179.8**
Volume	3	3.7*	1.4	1.8	2.3	2.4	2.3	2.9*	8.2**
Replicate	5	.4	1.0	2.6	.4	1.3	.5	.7	.3
NS	15	2.9**	3.3**	3.2**	5.9**	8.6**	8.3**	3.7**	2.4**
NV	9	4.4**	1.6	1.5	5.6**	7.8**	5.1**	1.7	13.1**
NR	15	.4	.8	1.2	.7	.5	.3	.6	.4
SV	15	1.4	2.6**	2.6**	8.1**	2.6**	5.8**	7.0**	4.8**
SR	25	.6	.8	1.2	.8	.9	1.7*	.5	.7
VR	15	1.0	1.3	1.1	.4	1.0	1.0	.7	.4

* Significant at the 0.05 percent level.
** Significant at the 0.01 percent level.

TABLE 10.—Mean number of particles (20 particles per six replications) within each size category generated by revolving sintered-sleeve nozzle

	Particle size, microns [1]							
	<10	10-14.9	15-19.9	20-29.9	30-49.9	50-74.9	75-99.9	>100
Sleeve pore size, microns:								
2	3.31a	2.86a	1.70c	2.23ab	4.53c	1.38c	2.24a	1.75a
10	1.83b	2.33b	2.05bc	1.82b	5.68a	3.08a	1.83ab	1.38a
40	1.89b	2.73a	2.48a	1.99ab	4.93bc	3.26a	1.31c	1.41a
60	1.79b	2.69ab	2.24ab	2.38a	5.25ab	2.26b	1.44bc	1.94a
Nozzle speed, r.p.m.:								
2,000	.42d	.52d	.57c	.84d	2.67c	4.36b	2.78b	7.83a
4,000	.34d	1.51c	2.17b	4.10a	2.45c	.80d	6.76a	1.86b
6,000	1.67c	3.54ab	3.58a	3.07b	1.03d	6.43a	.65c	.03c
8,000	2.78b	3.57ab	2.33b	1.26d	7.24b	2.79c	.02d	.00c
10,000	4.15a	3.67a	2.08b	.99d	8.66a	.45de	.10d	.00c
11,800	3.89a	3.10b	1.96b	2.36c	8.55a	.14e	.00d	.00c
Flow rate, ml./min.:								
15	2.39a	2.45a	2.10a	2.41a	4.69b	2.76a	1.77ab	1.42bc
30	2.00b	2.62a	1.88a	1.88b	5.46a	2.35ab	2.04a	1.81ab
45	2.49a	2.74a	2.26a	2.13ab	5.18ab	2.59ab	1.62ab	.99c
60	2.00b	2.81a	2.22a	2.01ab	5.06ab	2.27b	1.38b	2.27a
Replicate:								
1	2.27a	2.64a	2.21ab	2.19a	4.71b	2.45a	1.78a	1.76a
2	2.30a	2.61a	2.17ab	2.20a	4.98ab	2.48a	1.72a	1.53a
3	2.14a	2.58a	2.45a	2.08a	5.04ab	2.39a	1.67a	1.66a
4	2.22a	2.73a	2.19ab	2.14a	5.18ab	2.38a	1.40a	1.78a
5	2.02a	2.43a	1.93b	2.14a	5.58a	2.58a	1.85a	1.47a
6	2.29a	2.92a	1.76b	1.90a	5.10ab	2.70a	1.80a	1.53a
Average	2.206	2.653	2.116	2.106	5.099	2.495	1.703	1.621

[1] Means followed by the same letter are not significantly different (0.05).

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOUTHERN REGION
P. O. BOX 53326
NEW ORLEANS, LOUISIANA 70153

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF
AGRICULTURE
AGR 101

U.S.MAIL